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THIS ISSUE

THE STUDEBAKER
AUTOMATIC
TRANSMISSION



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The Studebaker Automatic Transmission

IN PREVIOUS ISSUES¹ we have reviewed the desirability and general characteristics of any automatic transmission, and have examined seven different solutions to the problem in the chronological order of their appearance. The fact that none of the seven was exactly like any other merely illustrates that there is not (and probably never will be) complete agreement on all details of the problem, and that like many such problems, several solutions are possible. A war correspondent could truthfully describe the development situation as "extremely fluid," especially since *all seven* transmissions have been of the fluid or hydraulic type.

Those three of the five passenger car transmissions which were of the torque converter type also had another point in common: they were used with relatively large engines having considerable inherent torque, consequently the transmission itself was not required to multiply engine torque by more than the ability of the converter alone.

Some American and most European automotive designers have felt that the most desirable compromise between the opposite requirements of high fuel economy and high road performance could be obtained by choosing a relatively small engine and by working it harder and therefore at higher efficiency during normal level-road driving. The main

disadvantage of such an engine is its lesser full throttle torque and associated lower flexibility of performance, however this disadvantage can be overcome by providing a standard gear box with more and larger torque multiplication ratios (and more shifts). But American drivers and especially the feminine contingent are increasingly objecting to even one gear shift during acceleration and will hardly choose to clash through the European's customary four or more. As always the American solution is to substitute an educated mechanism for manual dexterity — in short to use an automatic transmission. In brief, the importance and convenience of an automatic transmission increases with decreasing engine size.

During more than fifteen years of intensive study and experimentation with automatic transmissions The Studebaker Corporation and Borg-Warner Corporation² gradually evolved a list of seventeen design features which were deemed desirable for inclusion if at all possible in an automatic transmission for their cars.

At least five of these requirements were unique and original to the field of automatic transmissions. Furthermore several of the requirements appeared to be incompatible with some of the others. In short these aiming points were deliberately set higher than current knowledge of the art would apparently justify, yet through the combined efforts of Studebaker and Borg-Warner and the exercise of remarkable mechanical ingenuity *all* of these difficult goals have been realized and incorporated in an

¹Nov. 1946—"Automotive Hydraulic Transmissions"
Apr. 1947—"The Hydra-Matic Transmission"
Nov. 1947—"Automotive Hydraulic Transmissions, The Hydro-kinetic Torque Converter"
Nov. 1948—"Automotive Hydraulic Transmissions, The White Hydro-Torque Drive"
Nov. 1949—"The Buick Dynaflow Transmission"
Oct. 1950—"The Packard Ultramatic Drive"
Nov. 1950—"Chevrolet Powerglide Transmission"

²Detroit Gear Division



Courtesy of Long Mfg. Div., Borg-Warner Corp.

Figure 1 — Major assemblies, combination torque converter-fluid coupling.

automatic transmission which is now available as optional equipment at extra cost in all Studebakers.

DESCRIPTION, GENERAL

The Studebaker Automatic Transmission is briefly described as an air-cooled combination torque converter-fluid coupling with direct drive clutch assisted during acceleration by one automatic shift through a pair of planetary gear sets. In other words both the torque converter and the gear sets furnish torque multiplication during acceleration. The transmission therefore differs in this and several other respects from any of those previously studied.

Driver's Controls and Operation

The transmission requires only two driver's controls: (1) the now-familiar selector or control lever with its indicator quadrant mounted on the steering column and (2) the foot throttle. Since there is no clutch pedal, advantage has been taken of its absence to extend the top of the brake pedal considerably to the left so that it is readily used by either (or both) of the driver's feet. In addition to being a very desirable safety provision (the brake pedal is so easily found even by drivers not accustomed to the car), the extended brake pedal also permits a much more comfortable driving position for those drivers who have retrained themselves to use their left foot as their brake foot.

The selector quadrant indicates five selector lever positions which are arranged from left to right in the same now-standard order utilized in previous transmissions, namely, "P" (Park), "N" (Neutral), "D" (Drive), "L" (Low) and "R" (Reverse). However the selector quadrant is "gated" so that only the Drive and Neutral positions are on the same normal level. In other words shifts between Drive and Neutral are accomplished with a simple flip of the finger, but the selector lever must first be pulled towards the driver before it can be moved into the Park, Low, or Reverse positions. Since the Low and Reverse positions are adjacent on the same gate level, "rocking" the car in a snow bank by shifting from Low to Reverse is facilitated.

Although a new driver quickly becomes so accustomed to the "feel" of the selector level positions that he no longer needs to look at the quadrant, the quadrant is nevertheless lighted at night.

The Park Position provides a very convenient positive all-mechanical lock within the transmission which prevents the rear wheels from moving in either direction whether on level road or incline. Since the accidental engagement of this lock while the car was moving at considerable speed could be both dangerous and detrimental to any transmission, Studebaker has provided two different safety features. The first feature is a separate "gate" within the selector mechanism for the *Park* position which requires the driver to pull the lever towards him with conscious effort before either moving it into or out of the *Park* position. The second protective feature is a hydraulic interlock piston within the transmission which prevents engagement of the lock if the car is moving forward faster than 3 to 5 miles per hour. Even if the driver deliberately places the selector lever in the *Park* position while the car is moving at speed, no harm can result because the planetary gears are in their neutral position and the car will roll freely until a low enough speed is reached for the interlock piston to disengage and permit the parking pawl to engage the teeth of its gear.

A third general safety feature is incorporated by means of a starter cut-out switch located at the foot of the steering column which prevents the starter from functioning unless the selector lever is in either *Park* or *Neutral* positions. Those who have frantically manipulated a clutch, gear shift lever, hand brake, starter, foot-brake and foot-throttle while starting and moving a conventional car that has been parked on a grade will particularly appreciate the obvious safety, simplicity and convenience of this feature. This provision also prevents the damage to the starter or flywheel gear that would otherwise occur if the starter button were accidentally pressed (as by a child) while driving.

In Neutral Position, like the *Park*, the engine is completely disconnected within the transmission from the driving wheels, and can be started and operated, however the rear wheels are also free to move and the car will coast on a grade unless prevented by use of the brakes. *Neutral* position should be used if it is necessary to tow a car, and towing speed should be kept below 30 mph.

The Drive Position provides the normal forward driving range which is used for virtually all normal starting, acceleration, driving and hill climbing. In short once the driver has started the engine (in *P* or *N*) and has moved the selector lever to *D* he can sit back and enjoy himself. At

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a mere touch of the foot throttle the car moves forward, and shifts from intermediate gear to direct-drive high at a speed between 18 and 23 mph.³ Under full throttle acceleration, and to permit full use of both torque converter and intermediate gear, the single shift is postponed until a car speed of 36 to 42 mph³ is attained. During normal part throttle driving at any speed below 50 mph the driver can instantly obtain the superior acceleration or passing power provided in the intermediate gear by merely pressing the foot throttle to the floorboard. The transmission will then remain in intermediate gear and converter until either the throttle is momentarily released or the car attains a full throttle speed of 55 to 70 mph³, under which conditions it will automatically return to its normal direct-drive "high gear" operation. On deceleration the transmission automatically downshifts to intermediate gear at about 12 mph.

The Low Position provides an emergency ultra-powerful low gear which is occasionally useful for starting on and climbing very steep upgrades, for obtaining maximum engine braking while descending such grades, for "rocking" the car and difficult pulling in deep mud or snow, and for towing heavy loads for short distances. When used in descending grades and to avoid excessive engine speeds, the car should first be braked to below 40 mph before moving the selector lever into *Low*. Since no automatic shift can occur in the *Low* range, the transmission will remain in both converter operation and the *Low* planetary gearing until the driver moves his selector lever to some other position. The *Low* position also provides the ultimate in acceleration or getaway if the car is started in this position and the selector lever then moved to *Drive* at any speed below 40 mph and without releasing the foot throttle. Rocking out of mud, sand or snow is easily accomplished by depressing the foot throttle slightly and holding it while alternately moving the selector between *Drive* and *Low*.

The Reverse Position provides for moving the car backwards. Like the *Low* position it also utilizes the torque multiplying abilities of both the converter and the planetary gearing, and does not make any shift to a higher gear. A reverse interlock valve located in the transmission control system positively prevents either the accidental or intentional accomplishment of a shift into reverse when the car is moving forward at speeds above 5 to 10 mph.

Combination Torque Converter-Fluid Coupling

Figure 4 presents both a photographic cross section of the actual transmission and a highly schematic diagram of its principal mechanisms, with corresponding parts connected by dashed "leader lines" and designated by numbers and names.

The combination torque converter-fluid coupling which is readily identified in the top portion of either illustration is of the single-stage three-element type comprising the engine-driven converter casing with its contained impeller or pump (part 9), the turbine (part 6) and the stator (part 7) which latter is mounted on a free wheel unit (part 8) which in turn is mounted on a stationary reactor sleeve (part 10). Figure 1 presents an "exploded view" of the converter, turbine, stator and pump in order from left to right. It will be recalled from previous articles that in such a combination converter-coupling, the stator element is stationary whenever the engine input speed is greater than the converter output speed, consequently the torque-multiplying characteristics of the converter are smoothly and instantly available by merely pressing the engine throttle. As soon as the car has accelerated to such a speed that the converter's output speed is about 88% or more of its input, the free-wheel element of the single stator unlocks and permits the latter to rotate freely, thus automatically changing the converter into an efficient fluid coupling. Under "stall" condition (car stationary but engine running at from 1450 to 1650 RPM full throttle) the converter multiplies engine torque more than 2.0 times.

The shells, torus rings and blading of the converter are formed from sheet steel and the parts are assembled with a minimum of brazing. For example each blade is stamped with at least two integral "ears" or "tabs" which are inserted through corresponding slots in the shells and torus rings, and bent over on the opposite side. These tabs are readily visible in Figures 1 and 3. Since the converter is cooled by forced air circulation over its outside, the exterior of the converter pump casing is provided with a number of combination fan blades and cooling fins with an inclosing shroud spot-welded



Courtesy of Long Mfg. Div., Borg-Warner Corp.
Figure 2 — Major assemblies, direct-drive clutch.

³The exact shift speed varies with the car model; ranges shown include all models.



Courtesy of Long Mfg. Div., Borg-Warner Corp.

Figure 3 — Final Assembly, combination torque converter-fluid coupling with direct drive clutch and cooling fan.

to the converter pump casing. Outside air enters a duct near the left front wheel which conducts it to the converter housing where it is drawn in between the fan blades and discharged through louvers in the cover plate at the bottom of the converter housing. Such a cooling system is both direct in its action and independent from that of the engine.

Direct Drive Clutch

Even the best fluid coupling must allow some slippage between its driving and driven elements (being a hydrodynamic device a fluid coupling can not transmit *any* torque without *some* corresponding slippage). However, and to completely eliminate all fluid coupling slippage in direct drive, the manufacturer incorporated a clutch of unique design which, when engaged, connects the engine directly and wholly mechanically to the transmission output shaft. Since the engagement of the direct drive clutch "bypasses" or circumvents both the combination converter-coupling and *all* transmission gearing, it provides a direct mechanical "high" gear.

As schematically diagrammed in Figure 4, the Direct Drive Clutch consists of a backing plate (part 5), the driven plate (part 4) directly connected to the transmission output shaft (part 30) and a movable pressure plate (part 3). It can be seen from the schematic diagram that if hydraulic pressure is applied to the space between the flywheel plate and pressure plate, the latter will move axially towards the converter and "pinch" the driven plate between it and the backing plate — in other words engage the direct drive clutch.

In this detail the schematic portion of Figure 4 is oversimplified; the actual construction as illustrated in the left-hand part of Figure 4 is consid-

erably more refined and worthy of careful study. For example the actual flywheel with its ring gear is not a rigid part of the engine crankshaft, but is bolted to a thin flexible steel plate which in turn is bolted to the crankshaft flange. Riveted to the flywheel plate is a steel ring, the inner surface of which forms the hydraulic cylinder in which a large cup-shaped cast-iron hydraulic piston is installed. This piston is fitted with a synthetic rubber seal ring not only around its outer diameter but also around its central hole where the foremost part of the transmission mainshaft protrudes through it for the purpose of conducting the actuating oil pressure. The piston is readily visible in the central portion of the flywheel element of the direct drive clutch illustrated, Figure 2. The actual clutch pressure plate or piston (part 3, Figure 4, or Figure 2) is a smoothly finished stiff cast-iron plate hinged to the flywheel by means of three flexible steel straps which not only allow it to move axially in response to the urge of the underlying hydraulic piston, but permit it to transmit about half of the engine's torque to the clutch driven plate.

The single Direct Drive Clutch Plate (part 4, Figure 4, or Figure 2) embodies a conventional helical spring torsion member in its splined hub. Both of its rubbing faces are covered with a ground cork-synthetic rubber friction material which is concentrically grooved to promote smooth engagement.

The direct drive clutch Back Plate (part 5, Figure 4, or Figure 2) is a heavy steel pressing which is rigidly fastened to and driven by eight stud-bolts welded to the external lip of the hydraulic cylinder ring and readily visible in the Flywheel of Figure 2.

All of the converter and direct-drive clutch parts operate in oil and are contained in an oil-tight casting provided by the flywheel pressing and the converter pump casing. After assembly of the internal parts, the joint between the two halves of the casing is welded shut to form the fixed assembly illustrated in Figure 3. The circumferential welding bead is readily visible in both Figures 3 and 4. Considering the rather remote possibility that the internal parts of the assembly should require servicing, the practice will be to remove and replace the entire assembly. Such a "unit replacement" service method is already common with other automotive assemblies such as distributors, carburetors, fluid couplings, fuel pumps and generators.

The Planetary Gearing

A preliminary examination of the schematic diagram of Figure 4 will show that the transmission utilizes two simple planetary gears that are so interconnected and controlled by three "brake" bands, a multiple-disc clutch and two free wheel units that, with the previously described direct drive clutch, they provide a direct drive, two for

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ward gears, a neutral position, and a reverse.

When dictated by the driver through his selector lever, any of the three bands is contracted by its hydraulic servo mechanism so as to hold its drum stationary with respect to the transmission case. Similarly whenever the multiple disc clutch is engaged by hydraulic pressure, the sun gear and planetary carrier of the front planetary are locked together and all parts of the front planetary assembly must then rotate together like a solid coupling.

Since the ring gear (part 13) of the front planetary is always connected to and driven by the converter turbine (part 6), it is obvious that the gearing operates in partnership with and only when the converter is functioning, viz the low, intermediate and reverse ratios. Before studying the planetaries in detail however we must closely examine and understand the general construction and action of a free wheel unit, and in particular the highly ingenious use that Studebaker has made of two such free wheel units in partnership.

Free Wheel Units

A free wheel unit, also called a one-way clutch, is a device which allows one part to freely rotate in a given direction with respect to another, but which instantly and automatically "locks up" or refuses rotation whenever a reversal of rotation is attempted. In brief a free wheel unit acts much like the cruder pawl and ratchet device: unlike the latter however, the free wheel unit is quiet, smooth, instantly effective and without any backlash because it does not use teeth. While there are two general types of free wheel units, the "sprag" type illustrated in Figure 5 is now the most common. Considering for the moment only the centrally-placed Front Free Wheel Unit of Figure 5, it will be noted that a sprag type unit consists essentially of an inner and an outer race, both of which are perfectly cylindrical and concentric, with a number of interposed identical "sprags." The sprags are trapezoidally shaped or cam-like objects having a length somewhat greater than the radial distance between the inner and outer races. As a consequence the sprags must be inclined or "cocked" with respect to any radius of the races before they can be inserted. Unlike the few sprags illustrated in the figure, the actual sprag-type free wheel unit uses as many as can be inserted in the circumferential space available. Furthermore the sprags are retained in their locked position and caused to exert a slight pressure on both races by means of one or more circumferential "garter" spring retainers. From Figure 5 it can be seen that the outer race of the Front Free Wheel Unit can be freely turned clockwise with respect to the central race (shaft), or that the central race can be freely turned in a counter clockwise direction, the sprags in both cases merely

dragging mildly along one or both races. However, if the central shaft is turned clockwise, the sprags immediately "lock up" or "dig into" or "jam" between the inner and outer races, thus forcing both to move as a unit. Obviously if the outer race of this unit is held stationary, then the inner race can either remain stationary also, or turn only in a counter clockwise direction. The potentialities of such an apparently simple mechanism are tremendous as will be amply demonstrated in the following.

Figure 5 in its entirety is a more detailed and less schematic version of the corresponding elements of Figure 4. From Figure 5 the analytical reader will immediately make three important observations: (1) the front and rear free wheel elements are interconnected through their common inner race (2) the sun gear of the rear planetary is integral with this inner race and (3) the sprags of the two units are arranged oppositely. In summary, the action and interaction of these two opposed free-wheel units will determine the effect of the rear sun gear which in turn affects both of the planetary gear sets and the entire transmission.

In the subsequent description of the planetary gearing, the direction of rotation of any part will be described as if viewed by an observer at the front of and facing the car. For example the engine and all directly-connected parts will always rotate clockwise; the transmission output and propeller shafts will likewise rotate clockwise when the car is moving forward, and counter-clockwise when the car is backing.

Park and Neutral

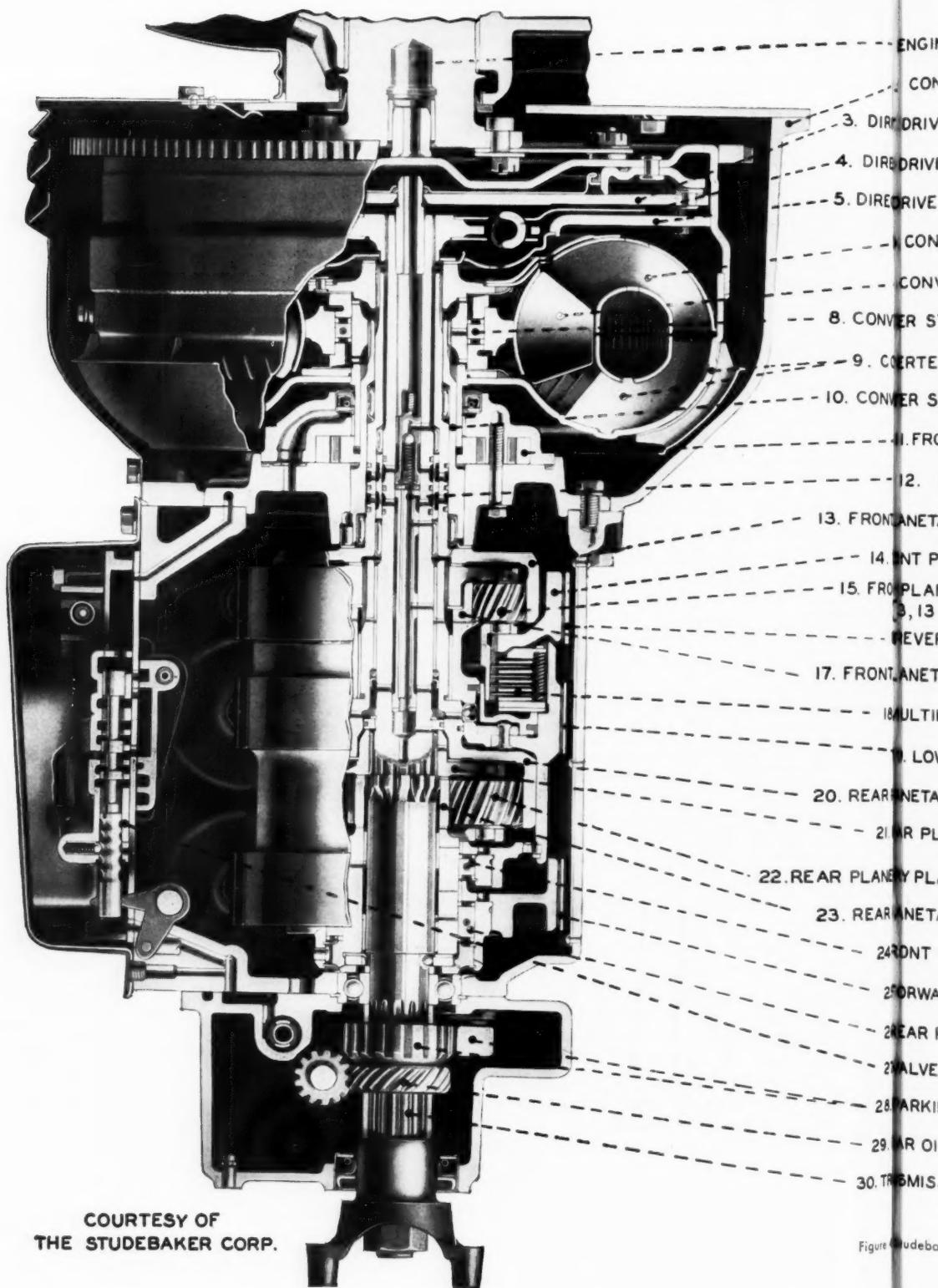
The Park and Neutral positions are alike in that all three bands, the direct drive clutch and the multi-disc clutch are disengaged: As a consequence the engine and the transmission output shaft are completely disconnected from each other and no torque can be transmitted from either to the other. In addition however, when the selector lever is moved to its Park position, the lever movement is mechanically transmitted through linkage to the parking gear pawl which is moved into and locks the parking gear (part 28, Figure 4) in a stationary position. As mentioned previously, an automatic interlock prevents engagement of the parking pawl if the car is moving forward too fast. (The interlock can not prevent engagement if the car is rolling backwards.)

Drive Position (Initial acceleration using both converter and intermediate gear)

Referring again to Figure 4, the forward-drive band (part 25), and multiple-disc clutch (part 18) are engaged while the direct-drive clutch (part 4) and the two other bands (parts 16 and 19) are

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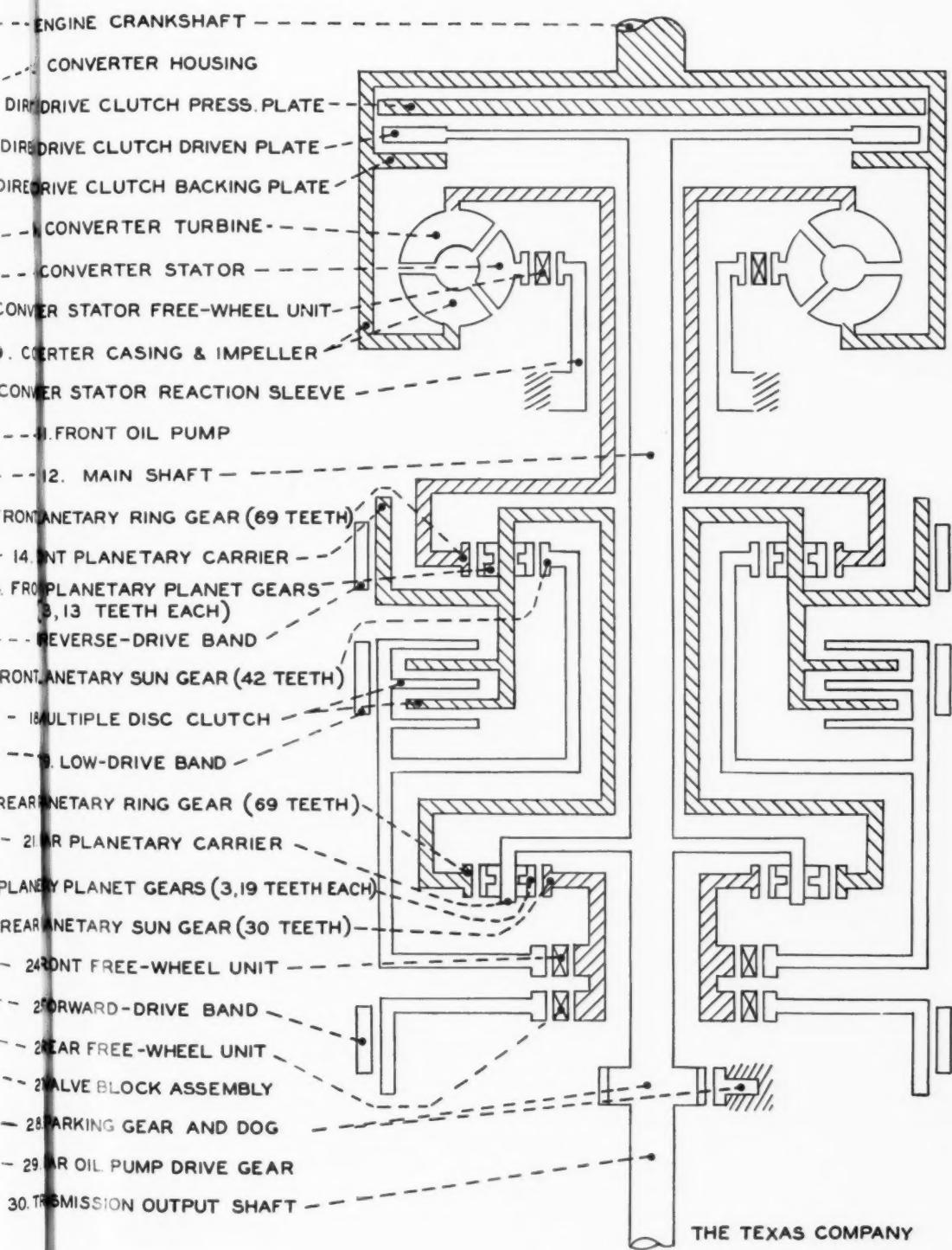


Figure 11-12. GM 4L60-E Automatic Transmission.

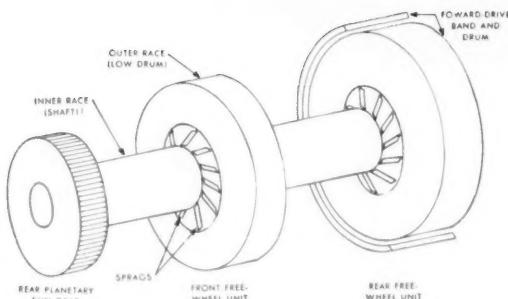


Figure 5 — Schematic sketch, front and rear free-wheel units.

released. Since the multiple-disc clutch (part 18) is connected between the front planetary carrier (part 14) and its sun gear (part 17), the entire front planetary is "locked up" as a solid coupling which merely transmits converter turbine torque to the rear planetary ring gear (part 20) and drives it clockwise. Since the Forward-drive band (part 25) is holding the outer race of the rear free wheel unit (part 26) stationary, the rear planetary sun gear is prevented from following its tendency towards counterclockwise rotation and is therefore able to serve as a stationary reaction gear. As a consequence, and as diagrammed in subfigure "a" of Figure 6, the planets precess in a clockwise direction driving their carrier which is connected to the transmission output shaft. Thus the rear planetary provides the so-called intermediate forward gear ratio of 1.43 which combined with the converter's stall ratio of 2.15 gives a maximum transmission torque multiplication ratio of 3.04. The fact that the rear planetary could not operate in this manner without the Forward-Drive Band being engaged is of course responsible for the band's name.

"Hill Holder"

A car equipped with this transmission can not roll backwards down a hill as long as the selector lever is in Drive position and the engine is running. As will be seen, this admirable safety feature is also provided by the versatile front and rear free-wheel units. For the car to move backwards, the rear planetary carrier (part 21, Figure 4) attached to the transmission output shaft must either be driven or be free to rotate in a counterclockwise direction. For this to occur any one of the following three "possibilities" must actually occur in the rear planetary: (1) if the sun gear is stationary, then the ring gear must be driven or be able to rotate rapidly counterclockwise (see subsketch "b," Figure 6) (2) if the ring gear is stationary, the sun gear must be driven or able to rotate counterclockwise (see subfigure c, Figure 6); (3) if both the ring gear and sun gear are free to rotate, then both must move counterclockwise (subfigure d,

Figure 6).

When in Drive position with engine running the engine-driven front pump furnishes oil pressure to engage and hold both the Forward Band and the Multiple Disc Clutch. With the Multiple Disc Clutch engaged, the Front Planetary is locked and rotates as a unit which drives both the rear planetary ring gear and outer race of the front free wheel unit in a clockwise direction. But all three of the foregoing "possibilities" require that the rear planetary ring gear either *rotate counterclockwise* or remain stationary, hence all three are *impossibilities* and the car can not roll backwards.

Of course the rear planetary ring gear is doubly prevented from reverse rotation by the front free wheel unit which would lock and attempt to rotate the rear sun gear counter clockwise, which in turn would be prevented by the combined action of the rear free wheel unit and the forward drive band.

In summary, the Hill Holder characteristic prevents accidental back-roll of the car but only if the engine is running and the selector is in Drive.

Drive (Direct or "high gear" without converter)

When the car has attained a speed between 18 and 42 mph (the exact speed being determined by foot throttle position), the transmission's governor causes oil pressure to be applied to the hydraulic piston bearing against the front side of the direct drive clutch pressure plate which engages this clutch. Meanwhile oil pressure has been maintained on the multiple disc clutch and the servo for the Forward Drive Band, and these also are engaged. With direct drive clutch engaged, engine torque is transmitted directly and unchanged by wholly mechanical means to the transmission output shaft.

Just before the direct drive clutch is engaged, the engine is driving the car through both the converter-coupling and the intermediate gear provided by the rear planetary, consequently engine and converter pump speed must be considerably higher while the converter turbine, front planetary and rear planetary ring gear are also running somewhat faster than the transmission output shaft. At the opposite extreme we have the rear planetary sun gear which is absolutely stationary. When the direct drive clutch is engaged, which actually constitutes an automatic shift into "high gear" the engine speed must be decreased and the speed of connected parts in the transmission must be increased or decreased to exactly correspond to the transmission output shaft. Furthermore all elements of the converter should rotate in the same direction and at exactly the same speed so as to eliminate all fluid circulation and consequent fluid losses. These synchronization problems are all uniquely solved in this transmission without requiring any of the usual

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complex governing or timing sequences, and the basic secret is again found in the action of the ubiquitous front and rear free-wheel mechanisms aided by the converter-coupling. Subfigures "a" and "e" (only) of Figure 6 show the "before and after" conditions of the rear planetary. Following is a short account of the myriad actions and reactions that must occur during the accomplishment of this apparently simple change.

Engine speed decreases during the engagement of the direct-drive clutch, but the engine through the converter still exerts a decreasing torque on the rear planetary ring gear. As the converter pump speed falls to and passes the turbine speed, a torque reversal occurs since the turbine is now attempting to drive its pump (and the engine) consequently the turbine is "braked down" by hydraulic means. The rear sun gear with the assistance of the rear free wheel unit initially remains stationary and furnishes necessary reaction to the planets which are also engaged in slowing down the ring gear. As the ring gear approaches synchronous speed, the sun gear breaks loose from the rear free wheel element and accelerates up to ring gear speed: the front free wheel element now operates to prevent it from ever exceeding the ring gear speed. During this whole fascinating synchronization process, the planets continue to rotate steadily with their carrier but slow down around their own axes and finally stop. While rotating around their own axes they act as intermediates by instantly adjusting the rapidly changing and opposing torques. At the conclusion of synchronization (which probably requires less than a second) the engine and all of the converter and planetary elements are rotating like solid couplings in the same direction and at the same speed as the transmission output shaft and a true all-

mechanical highly efficient direct drive has been achieved. Furthermore the synchronization has been accomplished so smoothly as to be generally imperceptible.

Low

During all operation in Low position both the low and forward-drive bands are applied and holding their drums stationary: the reverse band, multiple disc clutch and direct drive clutch are all released and entirely inactive. Engine torque is multiplied through the converter and applied to the ring gear of the front planetary. The sun gear of this planetary tends to turn counterclockwise but is prevented and held stationary both by the low band and by the combination of the front and rear free wheel units with the forward-drive band. The planetary carrier is accordingly driven in a clockwise direction, and the planetary as a whole accomplishes a torque multiplication of 1.61. Subfigure "a" of Figure 6 illustrates the planetary action. This doubly-multiplied torque is transmitted on to the ring gear of the rear planetary whose sun gear is likewise prevented from counterclockwise rotation by the rear free-wheel unit. As a consequence the rear planetary again multiplies torque by 1.435 times. In summary the Low position utilizes the torque multiplying abilities of the converter and both planetaries. Under stall conditions the maximum transmission torque multiplication ratio of the transmission as a whole is therefore $2.15 \times 1.61 \times 1.435$ or 4.96; when the converter is operating as a fluid coupling the corresponding figure is $1 \times 1.61 \times 1.435$ or 2.31.

Reverse

During reverse operation only the reverse band

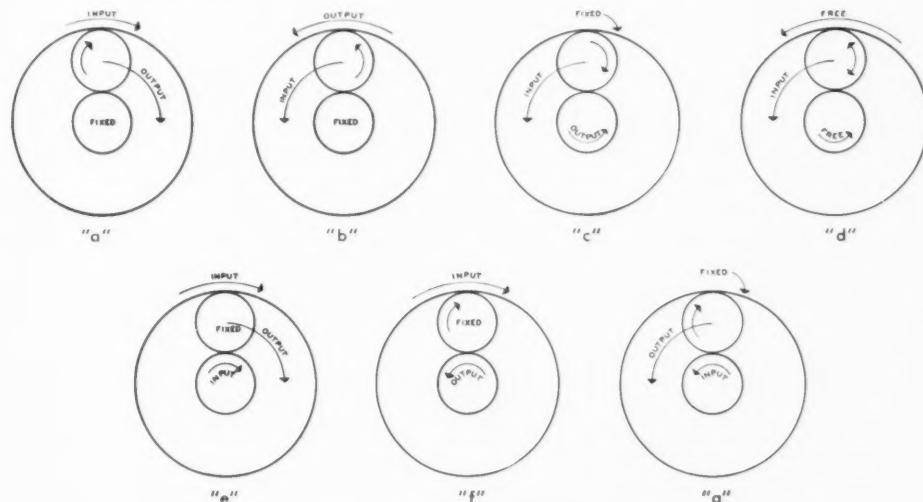
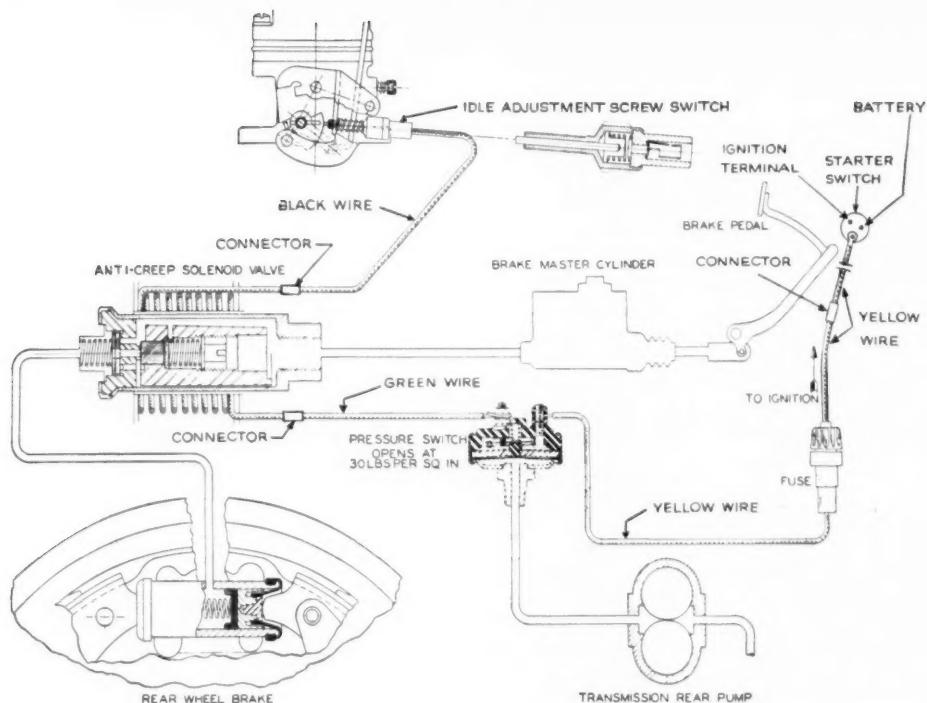


Figure 6 — Schematic diagrams of various planetary operations.



Courtesy of The Studebaker Corporation

Figure 7 — Anti-Creep System.

is applied; the other two bands and both clutches are released. Referring to Figure 4 it will be seen that engine torque is multiplied through the converter and applied to the ring gear of the front planetary. Since the low band (part 19) is holding the front planetary carrier stationary, the planets are driven clockwise around their own axes without precession, and they therefore drive the sun gear in a counterclockwise or reverse direction. The operation of the front planetary in this instance is illustrated in diagram "f" of Figure 6, and the resultant torque multiplication ratio is 0.608 which is another way of stating that this planetary is now actually "over-driving" in a reverse direction since its output speed is higher than its input with consequent reduction of input torque.

The output torque of the front planetary is delivered in a counterclockwise direction through its sun gear to the outer race of the front free wheel unit which locks (see Figure 5) and transmits the torque (still in counterclockwise direction) to the sun gear of the rear planetary. Since the ring gear of this planetary is held stationary by the low band, the planets are driven clockwise around their own axes and precess with their carrier, driving the transmission output shaft in a counterclockwise direction. Diagram "g" of Figure 6 illustrates this operation, and the resultant torque multiplication

through the rear planetary alone is 3.3. With the converter under stall conditions the total transmission torque multiplication ratio is $2.15 \times 0.608 \times 3.3 = 4.31$; when the converter is operating as a fluid coupling the corresponding figure is $1.0 \times 0.608 \times 3.3 = 2.009$.

Anti-Creep System

Cars equipped with either the "fluid coupling and gear" or torque converter types of automatic transmission usually have a tendency to "creep" slowly forward on level pavement when the transmission is in Drive and the engine is idling. The tendency is much more apparent if engine idle speed is set too high, or the carburetor throttle stop is resting on a fast-idle cam during warmup, or the transmission is in a lower gear range. While creep tendency is generally regarded only as a minor annoyance by the experienced driver, it can cause embarrassment and even an accident to a new driver who either is not alert to it, or who has not trained himself to the new "left-foot brake" driving method. Studebaker therefore decided to solve this problem and evolved its interesting and original anti-creep system illustrated in Figure 7. In brief the system operates on the principle that since a car is normally stopped by the application of its brakes, any tendency for it to subsequently creep

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forward could be controlled by arranging for the brakes to *remain applied* and holding the car until the driver gave some intentional "signal" to the mechanism of his intention to move the car forward. Since the foot throttle must be pressed to deliberately move the car, it furnishes an ideal "signal" for cancellation of the holding system.

The system affects only the two rear-wheel hydraulic brakes, and consists essentially of (1) a pressure control switch mounted on the right rear of the transmission and hydraulically connected to its rear oil pump (2) an anti-creep solenoid valve located on the brake master cylinder but interposed hydraulically between it and the brake lines to the rear wheels (3) an idle adjustment screw switch on the carburetor. The contact points of the pressure control switch are normally closed, and are opened when the rear oil pump develops a pressure of 30 psi or more. In other words this switch allows the anti-creep system to be operated when the car is either stationary, moving backwards, or moving forwards at speeds less than 3 to 5 mph, and prevents its operation otherwise. When the brakes are applied to effect a stop, the solenoid valve traps and retains a brake fluid pressure of about 200 psi in the rear brake cylinders which is sufficient to hold the car on the level and even a moderate down grade: it has no other effect on braking. The spring-loaded one-way trap valve can seat only when the solenoid coil is energized: even a momentary interruption of current to the solenoid winding will

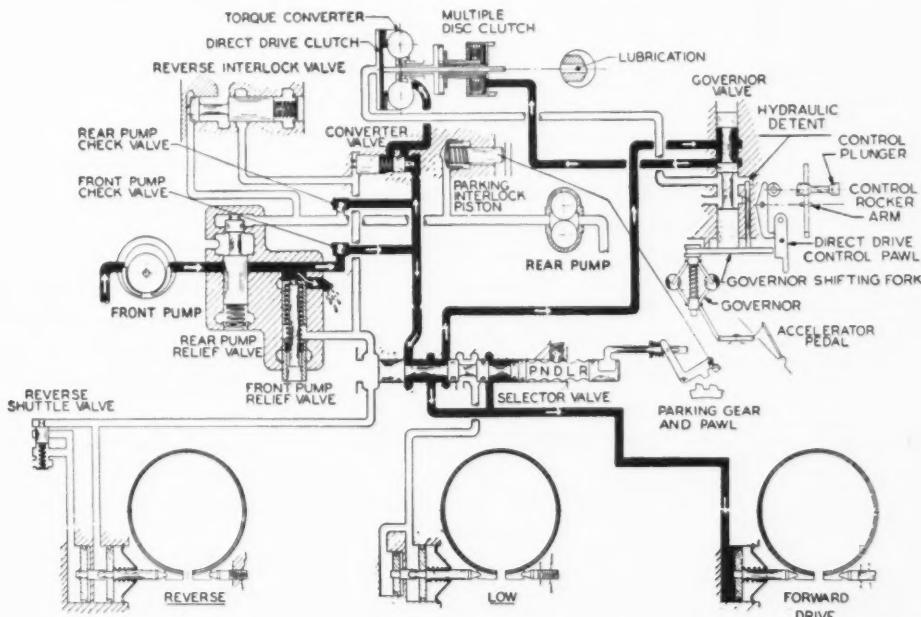
cause the solenoid plunger to push the trap valve off its seat and thus release the brakes. The idle adjustment screw switch takes the place of the simple screw ordinarily used to adjust engine idle speed, and contains two contact points that are closed as long as the carburetor throttle is closed to its idling position but which open instantly to de-energize the solenoid valve and release the brakes whenever the throttle is touched.

Hydraulic Control and Lubrication System

Figure 8 presents a very clear diagram of the relationship among the principal mechanisms in the hydraulic control system of this transmission and incidentally illustrates its operation in the Drive position when both the converter and intermediate gear are in use. Following are brief descriptions of the construction and operation of the principal parts which in conjunction with Figure 8 will permit the analytically minded to make a more thorough study of the hydraulic control system.

The Front Pump (also see part 11, Figure 4) is of the rotary or external-internal gear type concentrically mounted and driven by an extension from the converter pump, and operates whenever but only when the engine is running. Its function is to furnish oil under pressure to the converter, hydraulic control system, and lubrication system during idling, low speed and reverse operation.

The Rear Pump (also see part 29, Figure 4) is of the conventional external gear type located on



Courtesy of The Studebaker Corporation

Figure 8 — Hydraulic Control System.

the right rear side of the transmission case and driven by a spiral gear on the transmission output shaft. Its functions are to supply oil pressure to operate the transmission when the engine is started by pushing the car, and to supply the converter, control system and lubrication requirements at higher car speeds. Due to its incorrect direction of rotation, the rear pump would of course be ineffective during reverse gear operation.

The Valve Block Assembly (part 27, Figure 4) contains the following five control valves:

a. The Selector Valve is of the normal stepped-piston type located within the transmission's valve block assembly and mechanically linked to the driver's transmission control or selector lever on the steering column. It is the master valve which at the bidding of the driver, determines the functions of the transmission.

b. The Front Pump Relief Valve is of the spring-loaded sleeve type and regulates the oil discharge pressure from the front oil pump during operation in the Park, Neutral Drive and Low ranges at 80 psi. For operation in Reverse range however, the very high torque reaction of the reverse band requires that its holding capacity be increased by supplying its servo with an oil pressure of 200 psi. As Figure 8 indicates, this increase in pressure is accomplished by admitting oil pressure from the front pump to the interior of the relief valve, thus in effect strengthening its spring.

c. The Rear Pump Relief Valve of the spring-loaded differentially-stepped piston-type regulates oil discharge pressure from the rear pump at 80 psi. During normal forward driving when the capacity of the rear pump is ample for all the transmission's requirements and it is therefore possible and profitable to relieve the front pump, oil pressure from the rear pump is applied to the small end of the rear pump relief valve and is sufficient to force it downward which discharges all oil from the front oil pump at low pressure directly into the sump.

d. The Converter Valve which is actually two pistons with a spring between them, is provided to reduce the normal oil pump pressure of 80 psi to 27 psi for supply to the converter. When operating in Reverse range, the selector valve admits the 200 psi oil pressure used in that range to the left face of the left piston, forcing it to the right and increasing spring pressure to such an extent that the converter valve will also reduce the 200 psi oil pressure to the desired 27 psi for the converter.

e. The previously-mentioned Reverse Interlock Valve is a spring-loaded stepped piston which prevents application of the reverse band if the car is moving forward at more than about 5 mph. Under the influence of its spring the valve normally remains in its left hand position. However the left

face of the valve is subjected to oil pressure from the rear pump and whenever this pressure (which directly measures low car speeds) exceeds a small value, the valve moves to the right and opens a relief port in the supply line to the reverse servo which prevents application of the latter.

The Reverse Shuttle Valve is a spring-loaded piston in the reverse servo body which provides for both fast and smooth engagement of the reverse band by dividing the process into two steps. From Figure 8 it will be noted that the reverse band servo is of unique design employing two tandem pistons and cylinders of equal diameter. All of the oil initially admitted to the reverse servo is applied to the right hand piston which quickly moves to the right and provides a quick take up. As this piston stops, oil pressure continues to build up until the reverse shuttle valve is forced downward and high pressure oil is admitted to the left piston. The two pistons in concert then exert twice as much "holding" pressure on the reverse band, as either could accomplish alone.

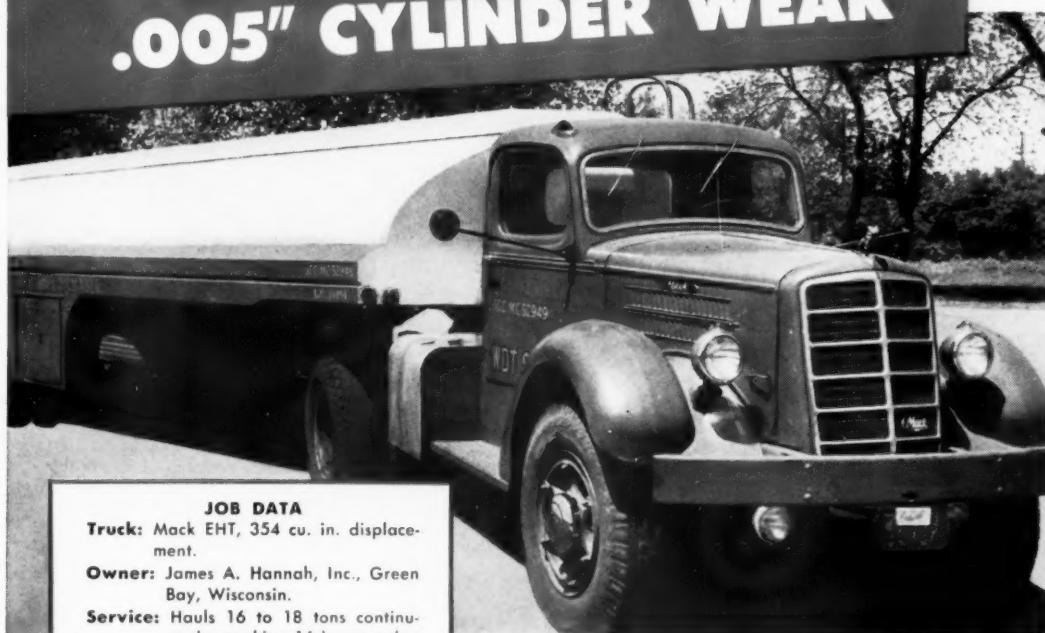
The Governor is of the spring-controlled flyball type and is driven by the same spiral gear (part 29, Figure 4) on the transmission output shaft as is used to drive the rear pump. Its sole purpose is to direct the engagement of the direct-drive clutch at the desired car speed by actuating the piston-type Governor Valve which admits oil to the clutch. The Governor Valve has two operating positions ("intermediate" and "direct") and incorporates a hydraulic detent to eliminate "hunting" between the positions. A linkage between the foot throttle and the governor spring increases the resistance applied to the governor weights as the throttle is opened, and thereby proportionately increases the car speed at which clutch engagement occurs.

The ball-type Front and Rear Pump Check Valves are provided in the discharge lines of their respective pumps to prevent the more active pump at any moment from discharging into its team-mate.

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All moving parts of this transmission that are not already submerged in oil are pressure-lubricated by the oil pumps through drilled passages. Because of the avoidance of any "timed shift," the fact that the direct drive clutch is the only planetary control device that must be engaged while the car is accelerating, and numerous other points of design and construction, this transmission operates with from $9\frac{1}{2}$ to $11\frac{1}{2}$ quarts of a premium type motor oil of the SAE 10W grade. Studebaker recommends the usual check on oil level every 1000 miles with drain and refill every 15,000 miles, repeatedly emphasizes that *premium* type oil must be used, and states "Purchase only brands of premium type oil marketed by reputable refineries."

IN 285,000 MILES - ONLY .005" CYLINDER WEAR



JOB DATA

Truck: Mack EHT, 354 cu. in. displacement.

Owner: James A. Hannah, Inc., Green Bay, Wisconsin.

Service: Hauls 16 to 18 tons continuously, working 16 hours a day with various drivers.

Hauling Radius: 200 miles.

Lubrication: Texaco D-303 Motor Oil SAE 30.

Engine protected by **TEXACO D-303 MOTOR OIL**

During 285,000 miles of operation, the engine in this hard-working Mack truck was lubricated exclusively with *Texaco D-303 Motor Oil*, and no major work was done on it. When finally taken down, cylinder wear was only **.005"** and all bearings were in perfect condition and were put back into service.

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especially designed to prevent formation of engine deposits — carbon, varnish, sludge. As this case history shows, it definitely guards against wear and protects bearings from corrosion. Use *Texaco D-303 Motor Oil* in your engines . . . for more trouble-free performance, and lower maintenance costs.

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